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STRESS-CORROSION CRACKING IN THE HAWK MOTOR CASE

by

William T. McClane

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18 January 1967

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STRESS-CORROSION CRACKING

IN THE HAWK MOTOR CASE

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Materials Engineering and Development Branch
Structures and Mechanics Laboratory
Research and Development Directorate
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Redstone Arsenal, Alabama 35809

ABSTRACT

Samples from the girth weld in the forward motor case of the HAWK missile were evaluated for susceptibility to stress-corrosion. Eight motor cases were fabricated from AISI-4132 steel using two different resistance weld cycles and four heat treatments. Welding in the heat treated condition gave the greatest resistance to stress-corrosion; however, the strength of the case was lowered in the heat affected zone. Samples that were normalized prior to quench and tempering had the poorest resistance to stress-corrosion. Welding, heat treating in salt, and sealing the crevice between the dome and the shell with a potting compound is the most effective method of preventing stress-corrosion in the HAWK motor case.

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ILLUSTRATIONS

Section I. INTRODUCTION

During a routine inspection of some HAWK missiles that had been in the field, a small crack was observed in one of the motor cases. The crack was in the girth weld that joins the forward closure dome to the motor case shell. Further inspection of other missiles revealed similar cracks in the same weld area. An ultrasonic test inspection indicated that a large number of motors were cracked in various degrees. A program was then initiated to develop a field fix for those missiles already produced.

A laboratory evaluation of several of the cracked cases pointed to stress-corrosion as the probable cause. The approach that was taken to prevent stress-corrosion on those cases that were not cracked was to seal the crevice between the shell and the dome with a potting compound. This involved selecting a suitable compound and devising a process for obtaining a satisfactory bond.

The compound that was finally chosen was Dow Corning 92-018 Aerospace Sealant. A sequence of cleaning operations was developed that produced a satisfactory bond and was adaptable for use in the field. Laboratory stress-corrosion tests substantiated both the material and the process as preventing stress-corrosion from starting and arresting it in those cases where it had already begun.

Teams were trained in the use of ultrasonic inspection and the application of the potting compound. These teams inspected all of the missiles deployed throughout the world. Those cases that were cracked were replaced with new motor cases. Those cases that were not cracked were cleaned and potted. A requirement that all new cases be potted was added to the motor case drawings.

As an additional protection against the recurrence of stress-corrosion in future motor cases, another program was established and will be described in this report. It involved an evaluation of various welding and heat treat cycles regarding their resistance to stress-corrosion.

Section II. DESCRIPTION OF TEST SPECIMENS

The motor case is fabricated from a low alloy high strength steel, AISI-4132, that is resistance seam-welded. Two different cycles have been certified and used in production. However, all of the welds were made with the same welding machine.

There were also two different methods of heat treating--one in salt and one in air. The initial cases were heat treated in air in accordance with the following schedule:

a. Heat to 1600°F for 1 hour.

b. Quench in oil at 130°F.

c. Temper at 825°F for 3 hours.

The present practice is to heat treat in salt in the following manner:

a. Heat to 1625°F for one-half hour in neutral salt.

b. Quench in salt at 400°F. Hold for 15 minutes.

c. Air cool.

d. Temper in salt at 800°F for 1 hour.

Eight welded cases were made for this study. They were designated:

A-1 Welded per cycle "A." Heat treated in salt.

A-2 Welded per cycle "A." Heat treated in air.

A-3 Welded per cycle "A." Normalized and then heat treated in salt.

A-4 Heat treated in salt then welded per cycle "A."

B-1 Welded per cycle "B." Heat treated in salt.

B-2 Welded per cycle "B." Heat treated in air.

B-3 Welded per cycle "B." Normalized and then heat treated in salt.

B-4 Heat treated in salt then welded per cycle "B."

All of the above cases were welded and heat treated at the manufacturer's plant, with two exceptions--A-3 and B-3, which were normalized and heat treated in the laboratory.

Upon receipt, the welded and heat treated sections were cut into specimens one-inch wide at the weld. A hole was then drilled in the end of the specimen to provide a means for applying a tensile stress on the weld. A welded dome is shown in Figure 1. A loaded stress-corrosion specimen is shown in Figure 2.

Figure 1. Dome Welded to Shell by Resistance Seam Weld.

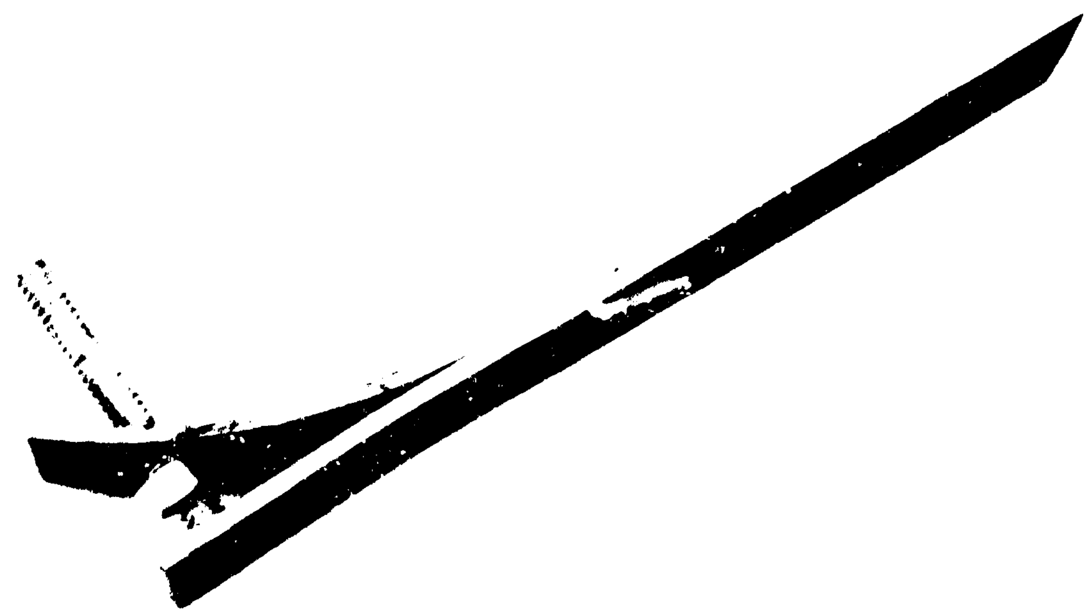

Figure 2. Stress-Corrosion Sample.

Section III. TEST PROCEDURE

One stress-corrosion specimen from each of the eight groups was torn apart in tension to determine the yield strength and the tear strength at the weld. Specimens were then loaded to 75 percent of the yield and 75 percent of the ultimate and placed in the salt spray cabinet. They remained in the cabinet exposed to a 5 percent NaCl fog until they failed or had withstood at least 360 hours exposure.

Section IV. RESULTS

The results of the stressed specimens in the salt spray cabinet are shown in Table I.

Table I

Case	Hours at 75% Elastic Stress	Hours at 75% Ultimate Stress
A-1	99, 99, 360+, 360+	327, 384+, 384+, 384+, 384+
A-2	99, 99, 99, 99, 99	15, 15, 135, 40, 15
A-3	20, 20, 53	20, 53, 53, 20
A-4	360+, 360+, 360+, 360+, 360+	384+, 384+, 384+, 384+
B-1	384+, 384+, 384+	384+, 112, 384+, 216
B-2	92, 384+, 15	384+, 15, 384+, 384+
B-3	92, 72, 40	15, 72, 15, 21
B-4	360+, 360+, 360+, 360+, 360+	40, 92, 384+, 72, 40

A cross-section of a typical weld before testing is shown in Figure 3. A similar section of a failed specimen is shown in Figure 4. Figure 5 shows the microstructure of a failed sample.

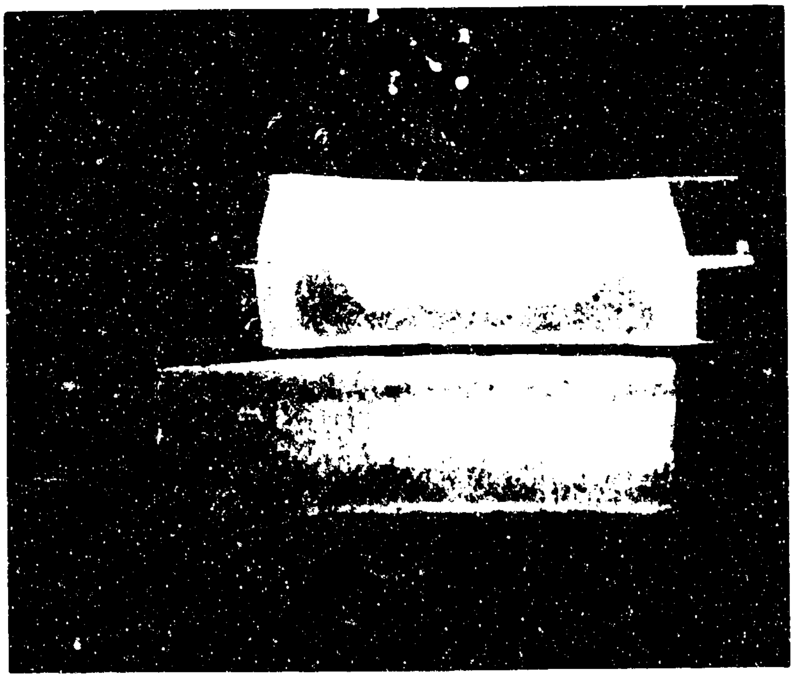

Figure 3. Section of Weld Before Testing.

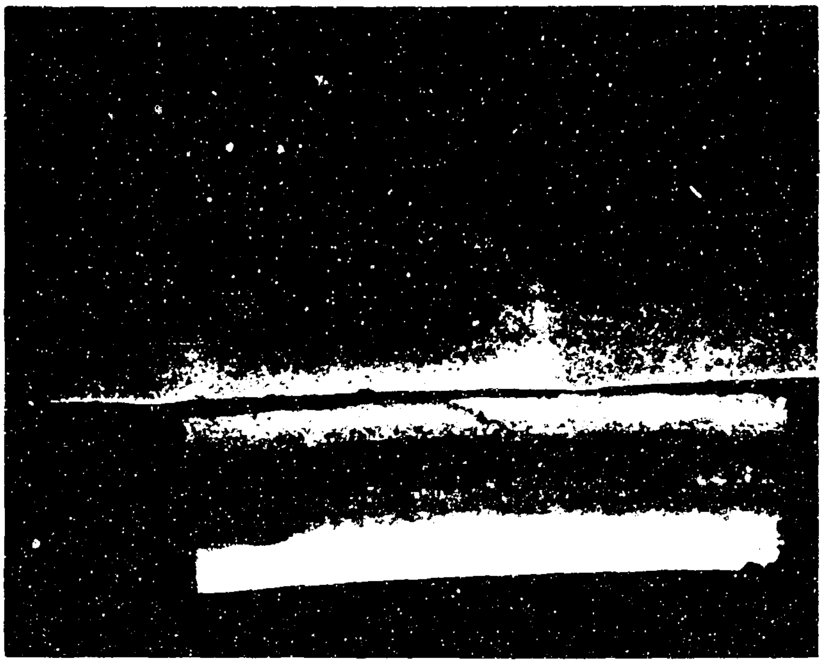

Figure 4. Failed Specimen.

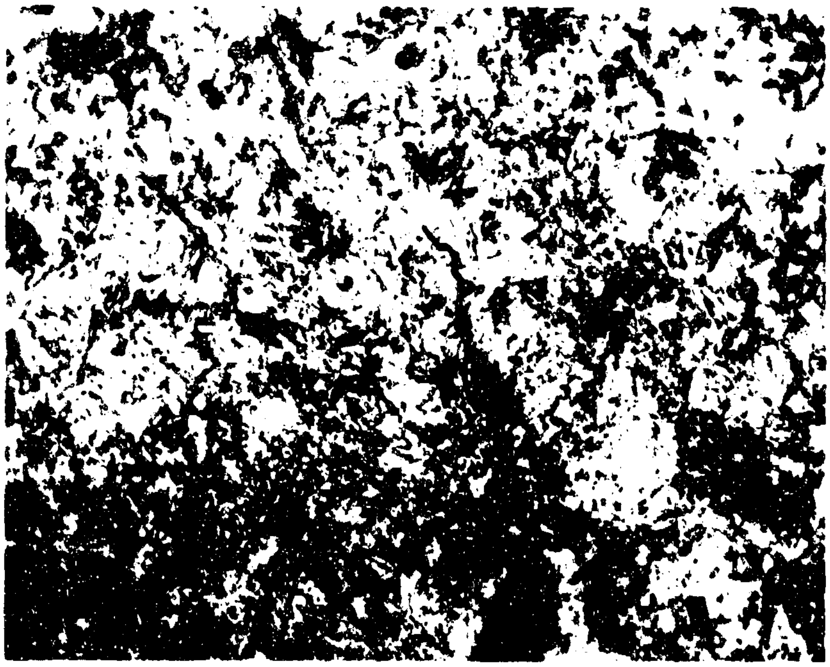

Figure 5. Microstructure of a Failed Sample.
500X Magnification.

Section V. DISCUSSION

A dendritic microstructure was typical of all the welded and heat treated specimens, as shown in Figure 6. There was no noticeable difference in any of them. The attendant segregation in such a microstructure suggests a mechanism whereby the stress-corrosion can proceed in accordance with one of the more widely held theories of stress-corrosion.

The composition gradient would be responsible for establishing local galvanic cells that electrochemically corrode the metal. Although stress is a necessary requisite, its exact role in the crack propagation has not yet been established. If the dendritic microstructure promotes stress-corrosion, then a normalizing heat treatment that would homogenize the structure should eliminate or greatly reduce its susceptibility.

A normalizing treatment consisting of heating to 1650°F, holding for one hour, and air cooling was performed on specimens A-3 and B-3. Following the normalizing treatment they were quenched and tempered in neutral salt per the standard heat treat cycle. The effect of this homogenizing treatment on the microstructure is shown in Figure 7. However, as Table I shows, the normalized specimens failed in considerably shorter times than any other group of samples.

The specimens that were heat treated and then welded, A-4 and B-4, had outstanding resistance to stress-corrosion. The only failures were those that were welded in accordance with cycle "B" and loaded beyond the yield point. Such a procedure, though, lowers the strength of the case because of the heat-affected zone on each side of the weld.

The susceptibility to stress-corrosion is lowered by the salt heat treating procedure as compared to specimens heat treated in air. This is contrary to the results of service life in the field. There have been no reports of motor case cracking in any of the cases that were heat treated in air, in spite of the fact that they were older cases and had been in service longer. This is undoubtedly the result of potting the crevice between the dome and the shell on all of the cases that were heat treated in air. This potting requirement was removed shortly after the salt bath heat treating process was initiated.

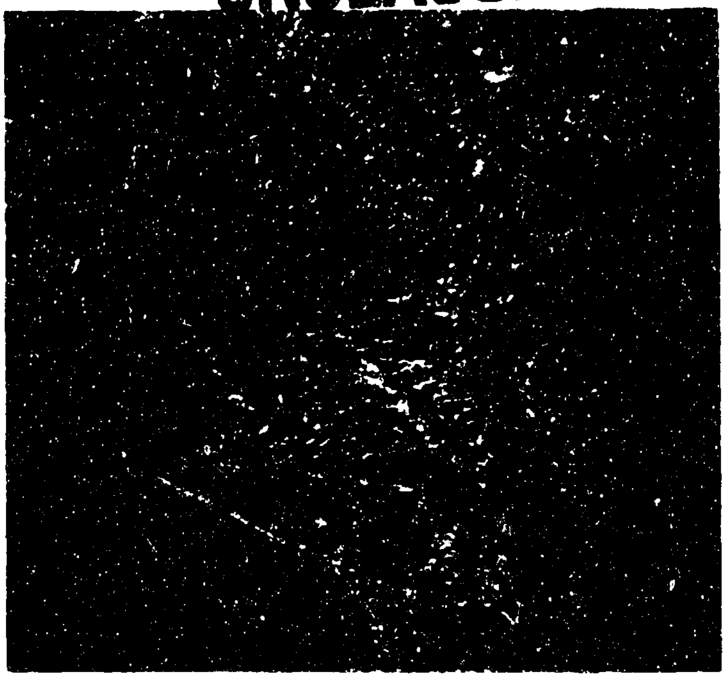

Figure 6. Dendritic Weld Area.
50X Magnification.

Figure 7. Effect of Homogenizing Treatment on Microstructure.
50X Magnification.

Section VI. CONCLUSIONS

A normalizing treatment prior to quenching and tempering has a detrimental effect on resistance to stress-corrosion cracking of AISI-4132.

The type of weld cycle had very little effect on the susceptibility to stress-corrosion.

Welding followed by heat treating in salt and sealing the crevice between the dome and the shell with a potting compound is the most effective method of preventing stress-corrosion in the HAWK motor case.

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